Palestine Polytechnic University
College of Engineering and Technology
Department of Mechanical Engineering
Mechanical Engineering Programs
ME 351 Machine Design I

First Exam – Part I – Closed Book

Instructor: Dr. Momen Sughayyer **Student Name:** Typical Solution
Date: October 11, 2011 **Student Number:** .....
Time: 60 Minutes (Part I + Part II) **Section:** .....

Notes to Students

- This exam has two parts: Part I is ***Closed-Book*** and Part II is ***Open-Book Only***.
- You can start with any question and you should answer all the exam questions.
- Write all solutions in the space provided. No sheets should be added to the exam.

Grading System

Question	Q1 = 10 Pt	Q2 = 10 Pt	Q3 = 10 Pt	Q4 = 10 Pt	Total Grade = 40 Pt
Grade					

Q1) (*10 Points*) Answer with TRUE or FALSE the following statements:

1. Mechanical engineering design in the discipline that deals with mechanical elements resistance to loads.
   ☒ **True** ☐ **False**
2. Strength is a property of a mechanical member that cannot be influenced by the treatment and the processing of the material.
   ☐ **True** ☒ **False**
3. Corrosion-resistant steels are from the type that has no impurities of chromium and often called stainless steels.
   ☐ **True** ☒ **False**
4. Mohr's Circle is a mathematical tool that is used to calculate the Cartesian components of stress in loaded elements.
   ☐ **True** ☒ **False**
5. A thermoset is a plastic that flows or is moldable when heat is applied to it.
   ☐ **True** ☒ **False**
6. The factor of stress concentration is commonly used in the existence of irregularities or discontinuities in loaded parts.
   ☒ **True** ☐ **False**
7. The purpose of case hardening is to produce a hard outer surface on a part of low-carbon steel while at the same tim retaining the ductility and toughness in the core.
   ☒ **True** ☐ **False**
8. Forging is very common metal working process. It is known among cold-working processes. Forging also produces a refined grain structure, which increases strength and ductility.
   ☐ **True** ☒ **False**
9. In the machine elements design process it is justified to have an expensive elaborated testing program for the designed parts, if its failure would endanger human life.
   ☒ **True** ☐ **False**
10. Cold working is the process of plastic straining below the recrystallization temperature in the elastic region of the stress-strain diagram.
    ☒ **True** ☐ **False**

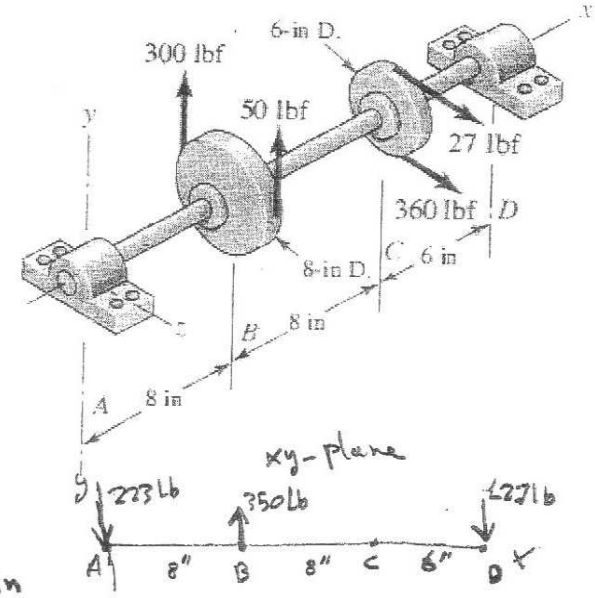
Palestine Polytechnic University
College of Engineering and Technology
Department of Mechanical Engineering
Mechanical Engineering Programs
ME 351 Machine Design I

First Exam – Part II – Open Book Only

Instructor: Dr. Momen Sughayyer
Date: October 11, 2011
Time: 60 Minutes (Part I + Part II)

Student Name: Typical Solution
Student Number:
Section:

Q2) (*10 Points*) The figure shows a shaft mounted in bearings at *A* and *D* and having pulleys at *B* and *C*. The forces shown acting on the pulley surfaces represent the belt tensions. The shaft is to be made of ASTM grade 25 cast iron using a design factor $n_d = 2.8$. What diameter should be used for the shaft?



$T_C = (360-27)\times 3 = 1000$ lb.in

$T_B = (300-50)\times 4 = 1000$ lb.in

⇒ xy-plane

$M_{B_y} = 223\times 8 = 1784$ lb.in

$M_{C_y} = 127\times 6 = 762$ lb.in

⇒ xz-plane

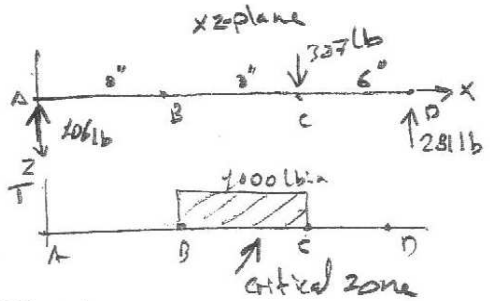
$M_{B_z} = 106\times 8 = 848$ lb.in

$M_{C_z} = 281\times 6 = 1686$ lb.in

The resultants

$$M_{RB} = \sqrt{(1784)^2 + (848)^2} = 1975 \text{ lb.in}$$

$$M_{RC} = \sqrt{(1686)^2 + (762)^2} = 1850 \text{ lb.in}$$



Therefore, point B is the critical one.

$$\tau_{xy} = \frac{16T}{\pi d^3} = \frac{16\times 1000}{\pi d^3}$$

$$\sigma_x = \frac{32 M_{RB}}{\pi d^3} = \frac{32\times 1975}{\pi d^3}$$

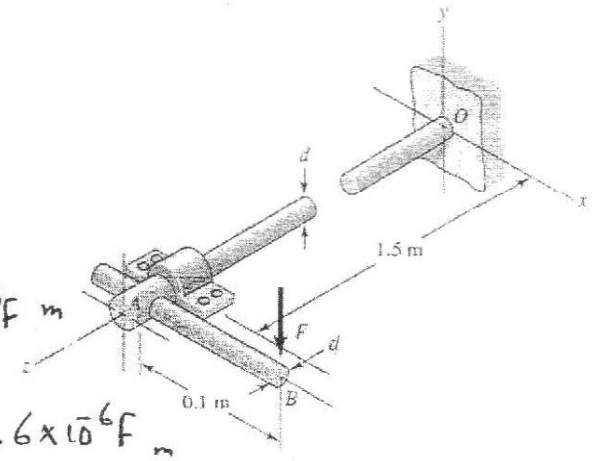
principal stress:

$$\sigma_{A,B} = \frac{\sigma_x}{2} \pm \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{xy}^2} = \frac{20.20}{d^3} \pm \sqrt{\left(\frac{20.20}{d^3}\right)^2 + \left(\frac{5.093}{d^3}\right)^2}$$

$$= \frac{20.06 \pm 11.27}{d^3}$$

$$\sigma_A = \frac{21.33}{d^3} = \frac{S_{ut}}{n_d} \Rightarrow d$$

Q3) (*10 Points*) The figure illustrates a torsion-bar spring *OA* having a diameter d = 12 mm. The actuating cantilever *AB* also has d = 12 mm. Both parts are of carbon steel. Use superposition and find the spring rate k corresponding to a force F acting at *B*.



* Member OA is subject to twisting only:

$$\theta = \frac{TL}{JG} \Rightarrow T = 0.1F$$

$$J = \frac{\pi}{32}(0.012)^4$$

$$\theta = \frac{(0.1F)(1.5)}{\frac{\pi}{32}(0.012)^4 (79.3)(10^9)} = 9.3 \times 10^{-4} F$$

deflection due to θ at B $\Rightarrow \delta_1 = \theta \times 0.1 = 9.3 \times 10^{-5} F$ m

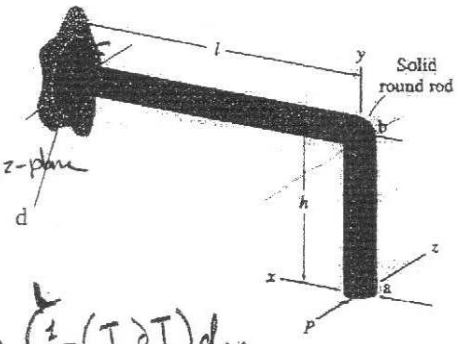
* Member AB is subject to bending

$$\delta_2 = \frac{FL^3}{3EI} = \frac{F(0.1)^3}{3(207)(10^9)(\frac{\pi}{64})(0.012)^4} = 1.6 \times 10^{-6} F \text{ m}$$

$$\delta_B = \delta_1 + \delta_2 = 9.3 \times 10^{-5} F + 1.6 \times 10^{-6} F = 9.46 \times 10^{-5} F \text{ m}$$

$$F = K\delta_B \Rightarrow k = \frac{F}{\delta_B} = \frac{1}{9.46 \times 10^{-5}} = 10.6 \text{ kN/m}$$

Q4) (*10 Points*) For the bracket shown in the figure, determine the deformation at point *a* in the direction of the force P using Castigliano's theorem. knowing that P is 100 lb, L is 12 in, h is 6 in, rod diameter is 0.75 in, and the bracket is made of low-carbon steel.



* member ab is under bending in yz- plane

$$M_b = Py \qquad y \to 0 \to h$$

* member bc is under bending in xz-plane and torsion in yz-plane

$$M_c = Px \qquad x \to 0 \to L$$

$$T = Ph$$

$$\delta_a = \frac{\partial U_a}{\partial P} = \int_0^h \frac{1}{EI}(M_b \frac{\partial M_b}{\partial P})dy + \int_0^L \frac{1}{EI}(M_c \frac{\partial M_c}{\partial P})dx + \int_0^L \frac{1}{GJ}(T \frac{\partial T}{\partial P})dx$$

$$\delta_a = \frac{1}{EI}\left[\int_0^h (Py)(y)dy + \int_0^L (Px)(x)dx\right] + \frac{1}{GJ}\int_0^L (Ph)(h)dx$$

$$\delta_a = \frac{1}{EI}\left(P\frac{y^3}{3}\Big]_0^h + P\frac{x^3}{3}\Big]_0^L\right) + \frac{1}{GJ} P h^2 x\Big]_0^L$$

END OF EXAM – GOOD LUCK

$$\delta_a = \frac{P}{EI}\left[\frac{h^3}{3} + \frac{L^3}{3}\right] + \frac{P}{GJ} h^2 L = P\left(\frac{1}{3EI}(h^3 + L^3) + \frac{L h^2}{GJ}\right)$$

Palestine Polytechnic University
College of Engineering and Technology

Department of Mechanical Engineering
Mechanical Engineering Programs
Course: ME 351 Machine Design I
First Exam

Instructor: Dr. Momen Sughayyer
Date: October 28, 2009
Time: 75 Minutes (Part I + Part II)

Student Name: Typical Solution
Student Number:.....
Section:.....

Notes to students: This exam is composed of two parts, part I is close-book and part II is open-book. You must start with part I, when you submit it to the exam supervisor, you can start with part II. Each student can manage the exam time according to his needs. All questions have to be answered, and the student can only use the book for part II.

Questions	Q1 = 10Pt	Q2 = 10Pt	Q3 = 10Pt	Q4 = 10Pt	Total Grade = 40Pt
Grade					

Part I – Close Book

Q1) (10 Points) Answer with TRUE or FALSE the following statements.

1. Mechanical engineering design is the discipline that deals with mechanical elements resistance to loads.
   ☒ True ☐ False
2. Strength is a property of a mechanical member that cannot be influenced by the treatment and the processing of the material.
   ☐ True ☒ False
3. Corrosion-resistant steels are from the type that has no impurities of chromium and often called stainless steels.
   ☐ True ☒ False
4. Mohr's Circle is a mathematical tool that is used to calculate the Cartesian components of stress in loaded elements.
   ☐ True ☒ False
5. A thermoset is a plastic that flows or is moldable when heat is applied to it.
   ☐ True ☒ False
6. The factor of stress concentration is commonly used in the existence of irregularities or discontinuities in loaded parts.
   ☒ True ☐ False
7. The purpose of case hardening is to produce a hard outer surface on a part of low-carbon steel while at the same time retaining the ductility and toughness in the core.
   ☒ True ☐ False
8. Forging is very common metal working process. It is known among cold-working processes. Forging also produces a refined grain structure, which increases strength and ductility.
   ☐ True ☒ False

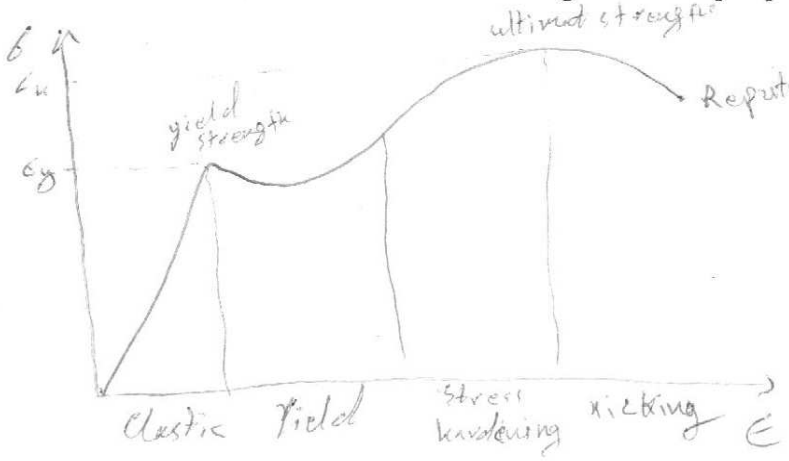
9. In the machine elements design process it is justified to have an expensive elaborated testing program for the designed parts, if its failure would endanger human life.
   ☒ True ☐ False
10. Cold working is the process of plastic straining below the recrystallization temperature in the elastic region of the stress-strain diagram.
   ☐ True ☒ False

Q2.1) (5 Points) List ten design specification that you believe are important for an airplane design.

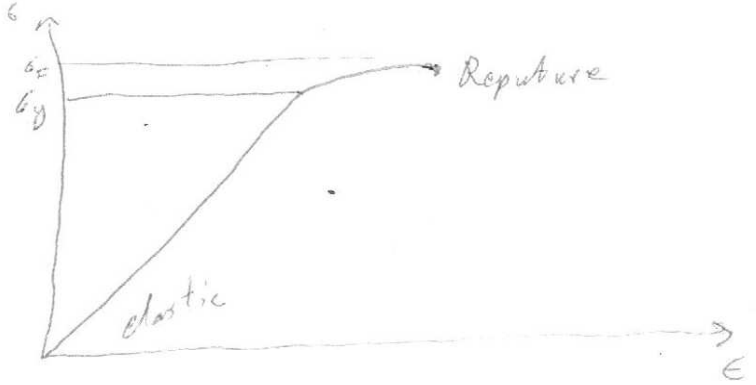
1. from Text Book. ⇒ Design Considerations
2.
3.
4.
5.
6.
7.
8.
9.
10.

Q2.2) (5 Points) Plot the Stress-Strain diagrams obtained from the standard tensile test for Ductile and Brittle materials showing the main properties.

Ductile



Brittle



Palestine Polytechnic University
College of Engineering and Technology

Department of Mechanical Engineering
Mechanical Engineering Programs
Course: ME 351 Machine Design I

First Exam

Instructor: Dr. Momen Sughayyer
Date: April 7, 2010
Time: 75 Minutes (Part I + Part II)

Student Name: .....
Student Number:.....
Section:.....

Notes to students: This exam is composed of two parts, part I is close-book and part II is open-book. You must start with part I, when you submit it to the exam supervisor, you can start with part II. Each student can manage the exam time according to his needs. All questions have to be answered, and the student can only use the book for part II.

Questions	Q1 = 5Pt	Q2 = 5Pt	Q3 = 10Pt	Q4 = 10Pt	Total Grade = 30Pt
Grade	3	3.5	9	6	22

Part I – Close Book

Q1) (5 Points) Answer with TRUE or FALSE the following statements.

1. Mechanical engineering design in the discipline that deals with mechanical elements resistance to loads.
   ☒ True ☐ False
2. Strength is a property of a mechanical member that cannot be influenced by the treatment and the processing of the material.
   ☒ True ☒ False
3. Corrosion-resistant steels are from the type that has no impurities of chromium and often called stainless steels.
   ☐ True ☒ False
4. Mohr's Circle is a mathematical tool that is used to calculate the Cartesian components of stress in loaded elements.
   ☐ True ☒ False
5. A thermoset is a plastic that flows or is moldable when heat is applied to it.
   ☐ True ☒ False
6. The factor of stress concentration is commonly used in the existence of irregularities or discontinuities in loaded parts.
   ☐ True ☒ False
7. The purpose of case hardening is to produce a hard outer surface on a part of low-carbon steel while at the same time retaining the ductility and toughness in the core.
   ☒ True ☐ False
8. Forging is very common metal working process. It is known among cold-working processes. Forging also produces a refined grain structure, which increases strength and ductility.
   ☒ True ☐ False

9. In the machine elements design process it is justified to have an expensive elaborated testing program for the designed parts, if its failure would endanger human life.

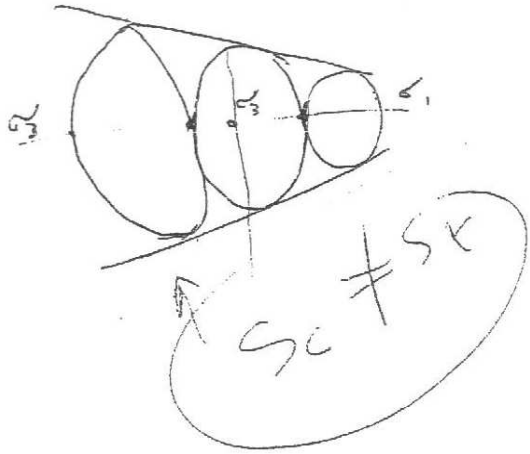
☒ True ☐ False

10. Cold working is the process of plastic straining below the recrystallization temperature in the elastic region of the stress-strain diagram.

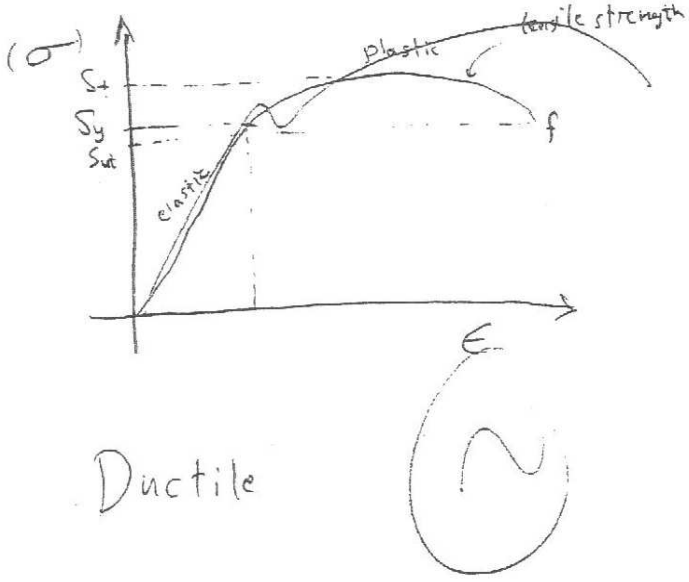
☐ True ☒ False

Q2.1) (2.5 Points) Explain when we use Columb-Mohr theory for ductile materials, what are its limits for design purposes compared to Distortion-Energy theory. Use sketch to explain use ideas.

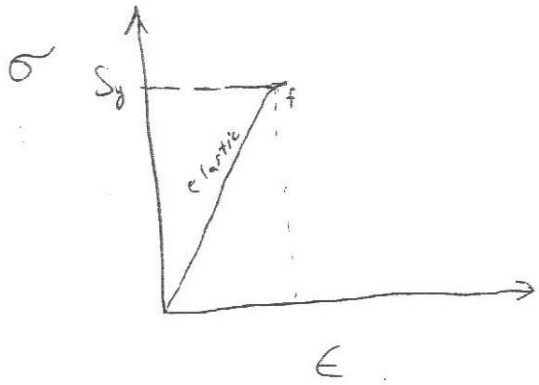
$\sigma' =$ DE



Q2.2) (2.5 Points) Plot the Stress-Strain diagrams obtained from the standard tensile test for Ductile and Brittle materials showing the main properties.



Ductile



brittle

Palestine Polytechnic University
College of Engineering and Technology

Department of Mechanical Engineering
Mechanical Engineering Programs
Course: ME 351 Machine Design I

First Exam

Instructor: Dr. Momen Sughayyer
Date: November 2, 2010
Time: 60 Minutes (Part I + Part II)

Student Name: Typical Solution
Student Number:
Section:

Notes to students: This exam is composed of two parts, part I is close-book and part II is open-book. You must start with part I, when you submit it to the exam supervisor, you can start with part II. Each student can manage the exam time according to his needs. All questions have to be answered, and the student can only use the book for part II.

Questions	Q1 = 15Pt	Q2 = 5Pt	Q3 = 20Pt	Q4 = 10Pt	Total Grade = 50Pt
Grade					

Part I – Close Book

Q1) (15 Points) Select the best answer in the following:

1. Which of the following do not affect the tensile yield strength of ductile materials?
   a. Temperature
   b. Fabrication processes
   c. Heat treatment
   (d) Loading
2. Mechanical engineering design in the discipline that deals with mechanical elements resistance to loads.
   ☒ True ☐ False
3. The ultimate strength of brittle materials is often the same in tension and in compression.
   ☐ True ☒ False
4. Corrosion-resistant steels are from the type that has no impurities of chromium and often called stainless steels.
   ☐ True ☒ False
5. Mohr's Circle is a mathematical tool that is used to calculate the Cartesian components of stress in loaded elements.
   ☐ True ☒ False
6. A thermoplastic is a plastic that flows or is moldable when heat is applied to it.
   ☒ True ☐ False
7. The factor of stress concentration is commonly used in the existence of irregularities or discontinuities in loaded parts.
   ☒ True ☐ False
8. Hot and cold fabrication processes generally do not have much influence on the strength of metals.
   ☐ True ☒ False
9. Forging is very common metal working process. It is known among cold-working processes. Forging also produces a refined grain structure, which increases strength and ductility.
   ☐ True ☒ False

10. In the machine elements design process it is justified to have an expensive elaborated testing program for the designed parts, if its failure would endanger human life.
☒ True ☐ False

11. Annealing or tempering cannot be used on hot or cold worked metal parts to obtain uniform material properties and lower residual stresses.
☐ True ☒ False

12. Ductile materials do not behave as springs in the elastic rang.
☐ True ☒ False

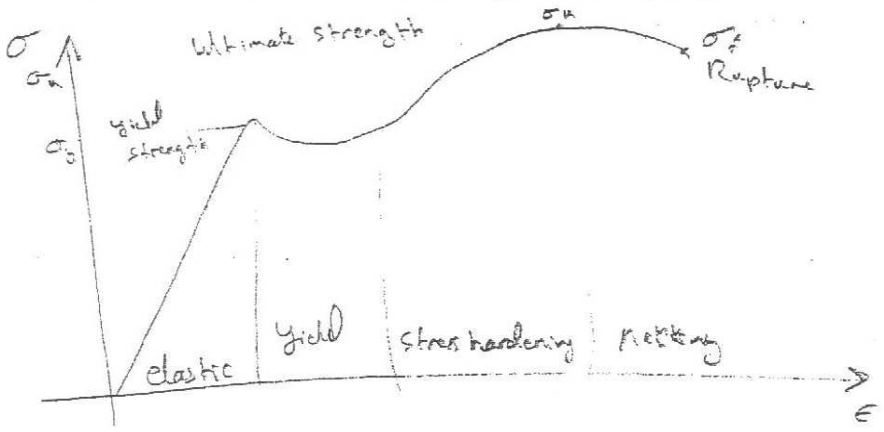
13. Extrusion, forging, and cold working improve materials strength properties.
☒ True ☐ False

14. The yield strength of steel is often quite different in tension than in compression.
☐ True ☒ False

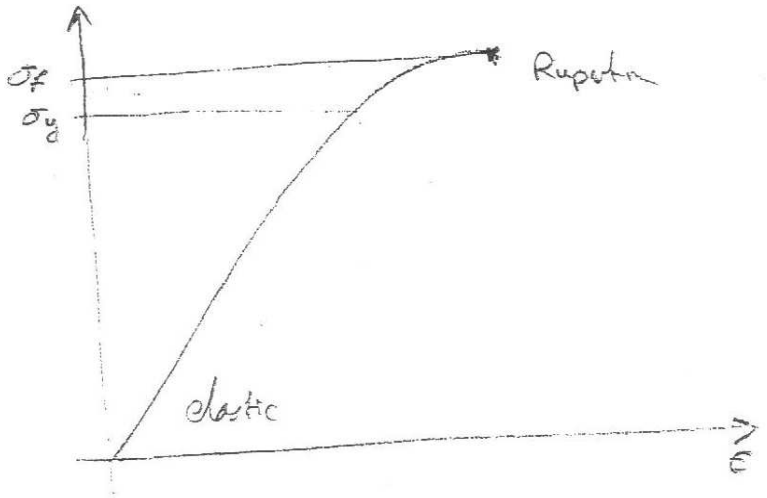
15. Geometric stress concentration factors are used to account for stress increases in the neighborhood of material changes.
☒ True ☐ False

Q2) (5 Points) Plot the Stress-Strain diagrams obtained from the standard tensile test for Ductile and Brittle materials showing the main properties.

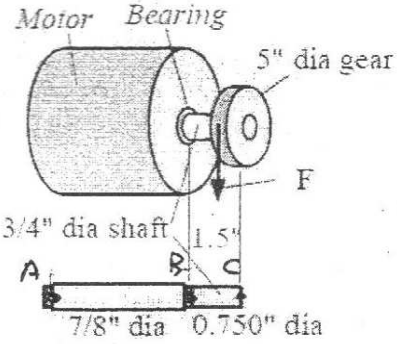
Ductile



Brittle



(15 Points) The gear is mounted on a 3/4 inch diameter shaft extending out of electric motor. The motor transmits 5 hp through the gear to the driven machinery at 1800 rpm. The shaft is made from 7/8 inch diameter cold-drawn steel that has S_y = 80 ksi and an S_{ut} = 120 ksi. The external portion of the shaft is machined from 7/8 inch to 3/4 inch with a 1/32 inch fillet radius at the bearing. Based on infinite life and using ASME-Ellipse method, determine the factor of safety of the shaft.



- Loads:- $P = T\omega = \frac{T*n}{63025} \Rightarrow T = \frac{63025*5}{1800} = 175$ lbin

$F = \frac{T}{r} = \frac{175}{2.5} = 70$ lb

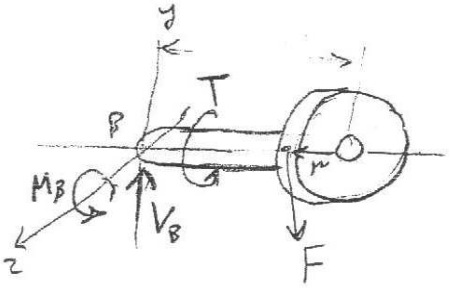
- Statics:- -For this case, the most critical section is the one at bearing B. =>

-This point is subject to shear for equal to the load F, bending moment equal to 1.5F, and Torque equal to load T.

$\Sigma F_y = 0 = V_B - F \Rightarrow V_B = F = 70$ lb

$\Sigma M_z = 0 = M_B - 1.5F \Rightarrow M_B = 1.5 \times 70 = 105$ lbin

$\Sigma M_y = T \Rightarrow T = 175$ lbin , free to Rotate



- Stress Concentrations: $\frac{r}{d} = \frac{1/32}{3/4} = 0.42$, $\frac{D}{d} = \frac{0.825}{0.750} = 1.17$

$K_t \cong 2.0$, $q = 0.75 \Rightarrow K_f = 1.75$

$K_{ts} = 1.7$, $q_s = 0.81 \Rightarrow K_{fs} = 1.57$

- Fatigue Strength:

$S_e' = 0.5 * S_{ut} = 0.5 * 120 = 60$ ksi

$k_a = 2.7 * 120^{-0.265} = 0.76$, $k_b = 0.879 (0.75)^{-0.107} = 0.9 \Rightarrow k_c = k_d = k_e = k_f = 1$

$S_e = (0.76)(0.9)(60) = 39.4$ ksi

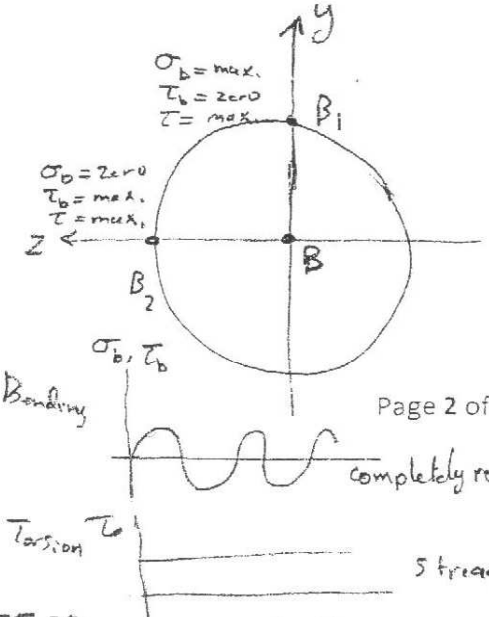
at point $B_1 \Rightarrow \sigma_b = K_f \frac{32 M_b}{\pi d^3} = 1.75 \left(\frac{32 * 105}{\pi (0.75)^3}\right) = 4.445$ ksi

$\tau_b = 0$

$\tau = K_{fs} \frac{16 T}{\pi d^3} = 1.57 \left(\frac{16 * 175}{\pi (0.75)^3}\right) = 2.11$ ksi

$\sigma_a = \sigma_b = 4.445$ ksi , $\sigma_m = 0$

$\tau_a = 0$, $\tau_m = \frac{\tau}{2} = 1.05$ ksi



$\sigma_a' =$

$\sigma_m' =$

$\left(\frac{n \sigma_a'}{S_e}\right)^2 + \left(\frac{n \sigma_m'}{S_{ut}}\right)^2 = 1 \Rightarrow$

=> at point B, use the same procedure with $\sigma_b = 0 \Rightarrow \sigma_a = \sigma_m = 0$, $\tau = \frac{16T}{\pi d^3}$

Palestine Polytechnic University
College of Engineering and Technology
Department of Mechanical Engineering
Mechanical Engineering Programs
ME 351 Machine Design I

First Exam

Instructor: Dr. Momen Sughayyer
Date: March 11, 2012
Time: 60 Minutes

Student Name: Typical Solution
Student Number: .....
Section: .....

Notes to Students

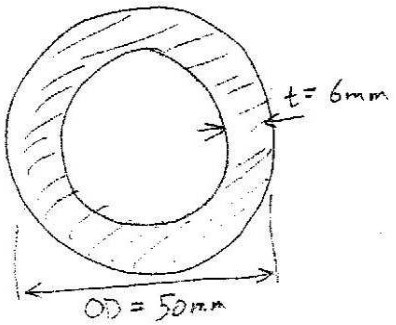
- This exam is ***Open-Book***, all questions have to be answered, and you can only use the book.
- Write all solutions in the space provided. No sheets should be added to the exam.
- Each student can manage the exam time according to his needs.

Grading System

Question	Q1 = 10 Pt	Q2 = 20 Pt	Q3 = 10 Pt	Total Grade = 40 Pt
Grade				

Q1) (*10 Points*) **An AISI 1040 cold-drawn steel tube has an OD = 50 mm and wall thickness 6 mm. What maximum external pressure can this tube withstand if the largest principal normal stress is not to exceed 80 percent of the minimum yield strength of the material?**

AISI 1040 CD $\Rightarrow S_y = 490$ MPa
From Table A-20/pp 1040



$r_o = \frac{OD}{2} = \frac{50}{2} = 25\,mm$

$r_i = \frac{OD-2t}{2} = \frac{50-12}{2} = 19\,mm$

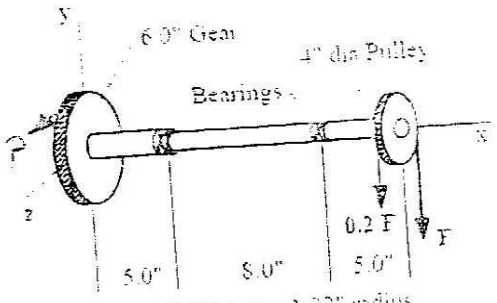
$S_{all} = 0.8\,S_y \Rightarrow \sigma_{t,max}$

$\sigma_{t_{max}} = \frac{2P_o r_o^2}{r_o^2 - r_i^2} \Rightarrow$

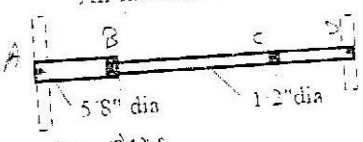
$P_o = \frac{(r_o^2 - r_i^2)}{2r_o^2} S_{all}$

$P_o = \frac{(25^2 - 19^2)}{2(25)^2}(0.8 \times 490 \times 10^6) =$

2) (20 Points) For the shaft subjected to the forces shown in the figure, determine the allowable value for the force *F*. Include stress concentration, assume the factor of safety is to be 1.6 and the shaft is made from 4140 normalized steel.



All fillets are 1.32" radius

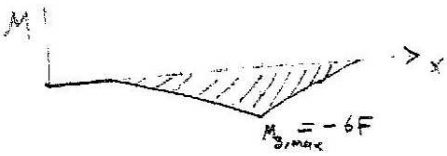


xy-plane:

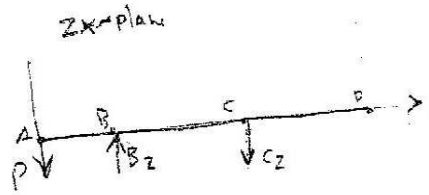
$\Sigma M_C = 0 = 13P - 8B_y \Rightarrow B_y = 1.625F$

$\Sigma F_y = 0 = -P - C_y + B_y \Rightarrow C_y = 0.375F$

$M_{y,max} = 6F$



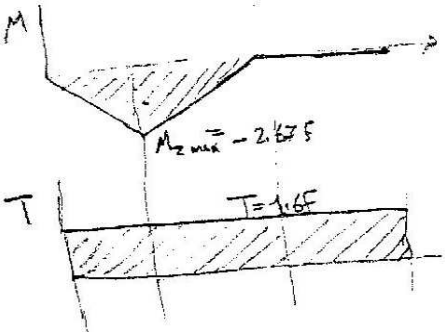
xz-plane:



$\Sigma M_C = 0 = 13P - 8B_z \Rightarrow B_z = 0.625F$

$\Sigma F_z = 0 = -P - C_z + B_z \Rightarrow C_z = 0.375F$

$M_{z,max} = 2.625F$



The max bending moment is at C, but stress concentration is present at B, which means that both points must be check for stress:

at point C, no stress concentration:

$$\sigma_x = \frac{M_z c}{I} = \frac{32M}{\pi d^3} = \frac{32(6F)}{\pi(0.5)^3} = 48.9F$$

$$\tau_{xy} = \frac{Tc}{J} = \frac{16T}{\pi d^3} = \frac{16(1.6F)}{\pi(0.5)^3} =$$

at point B, Stress concentration is present.

$$\sigma_x = K_t\left(\frac{32M}{\pi d^3}\right) =$$

$$\tau_{xy} = K_s\left(\frac{16M}{\pi d^3}\right) =$$

From tables

$K_t =$

$K_s =$

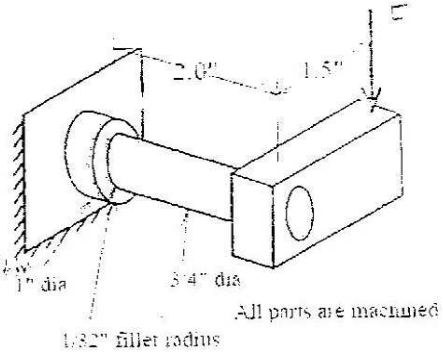
From tables

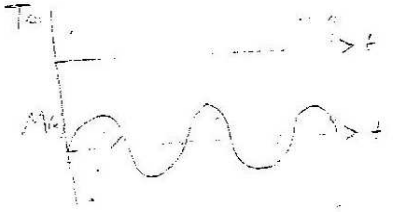
$S_y =$

We calculate principal stresses or using the Mohr circle radius $\Rightarrow \tau_{max} = \sqrt{\left(\frac{\sigma_x}{2}\right)^2 + \tau_{xy}^2}$ for each case $\Rightarrow$ the higher value must be less than $\frac{S_y}{2n}$, $n = 1.6$

$$\tau_{max} < \frac{S_y}{2(1.6)}$$

Q2) (*15 Points*) The stub shaft shown in gray color is a AISI 1050 cold-drawn steel, it is designed to transmit 15 hp at a speed of 500 rpm, machined to the required shape. Determine the factor of safety of for this shaft based on ASME-Elliptic method.





$T_m = \frac{P}{\omega} = \frac{63025\,P}{n} = \frac{63025 \times 15}{500} = 1890.75$ lbf·in

$F = \frac{T}{1.5} = 1260.5$ lbf

$M_a = 2F = 2521$ lbf·in

$T_a = M_m = 0$

— Stress Concentration at section A1:

$\frac{D}{d} = \frac{1}{3/4} = 1.33$, $\frac{r}{d} = \frac{1/32}{3/4} = 0.042 \Rightarrow K_t = 1.9$ from table A-15-9

$\Rightarrow K_{ts} = 1.6$ from table A-15-8

From figure 6-20 $\Rightarrow q = 0.65 \Rightarrow K_f = 1 + q(K_t - 1) =$

From figure 6-21 $\Rightarrow q_s = 0.7 \Rightarrow K_{fs} = 1 + q_s(K_{ts} - 1) =$

— Endurance limit and its corrections:-

$S_e' = 0.5\,S_{ut} = 50$ kpsi

machined surface $\Rightarrow k_a = 2.7(S_{ut})^{-0.265} =$

bending + torsion $\Rightarrow k_b = \left(\frac{3/4}{0.3}\right)^{-0.107} =$

$k_c = k_d = k_e = k_f = 1$

$S_e = k_a k_b S_e' =$

— Stresses at section A:

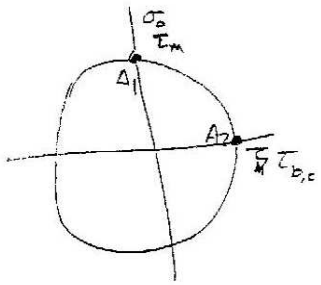
Bending $\Rightarrow \sigma_a = k_f \frac{M_a}{I/c} = k_f \frac{32 M_a}{\pi d^3} =$

$\sigma_m = 0$

Torsion $\Rightarrow \tau_m = k_{fs} \frac{T_a}{J/c} = k_{fs} \frac{16\,T_m}{\pi d^3} =$

$\tau_a = 0$

Bending shear $\Rightarrow \tau_{b,a} = \frac{kVQ}{It} =$



END OF EXAM – GOOD LUCK

at surface during rotation $\tau_m = 0$

$\Rightarrow$ at A2: Eq. 55.56 $\Rightarrow \sigma_a'$, σ_m'

Eq. 55.56 at A1 $\Rightarrow$

$\sigma_a' =$

$\sigma_m' =$

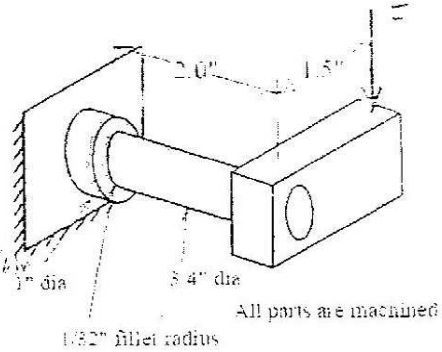
$\Rightarrow \left(\frac{n\sigma_a'}{S_e}\right)^2 + \left(\frac{n\sigma_m'}{S_{ut}}\right)^2 = 1$

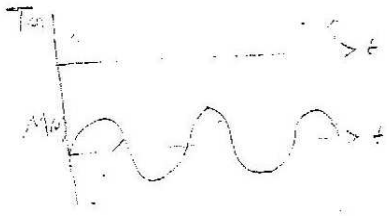
$\left(\frac{n_2\sigma_m'}{S_e}\right)^2 + \left(\frac{n_2\sigma_m'}{S_{ut}}\right)^2 = 1$

$n_1 =$

$n_2 =$

Q2) (*15 Points*) The stub shaft shown in gray color is a AISI 1050 cold-drawn steel, it is designed to transmit 15 hp at a speed of 500 rpm, machined to the required shape. Determine the factor of safety of for this shaft based on ASME-Elliptic method.





$T_m = \frac{63025P}{n} = \frac{63025 \times 15}{500} = 1891.25$ lbf·in

$F = \frac{T}{1.5} = 1261$ lbf

$M_a = 2F = 2522$ lbf·in

$T_a = M_m = 0$

— Stress Concentration at section A:

$\frac{D}{d} = \frac{1}{3/4} = 1.33$, $\frac{r}{d} = \frac{1/32}{3/4} = 0.042 \Rightarrow K_t = 1.9$ from table A-15-9

$\Rightarrow K_{ts} = 1.6$ from table A-15-8

From figure 6-20 $\Rightarrow q_t = 0.65 \Rightarrow K_f = 1 + q_t(K_t - 1) =$

From figure 6-21 $\Rightarrow q_s = 0.7 \Rightarrow K_{fs} = 1 + q_s(K_{ts} - 1) =$

— Endurance limit and its Corrections:-

$S_e' = 0.5 S_{ut} = 50$ kpsi

machined surface $\Rightarrow k_a = 2.7(S_{ut})^{-0.265} =$

bending + torsion $\Rightarrow k_b = \left(\frac{3/4}{0.3}\right)^{-0.107} =$

$k_c = k_d = k_e = k_g = 1$

$S_e = k_a k_b S_e' =$

— Stresses at section A:

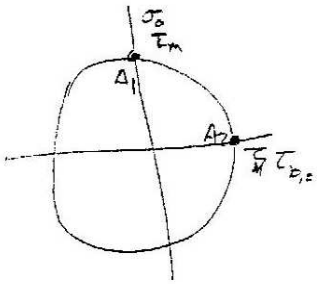
Bending $\Rightarrow \sigma_a = K_f \frac{M_a}{I/c} = K_f \frac{32 M_a}{\pi d^3} =$

$\sigma_m = 0$

Torsion $\Rightarrow \tau_m = K_{fs} \frac{T_a}{J/c} = K_{fs} \frac{16 T_m}{\pi d^3} =$

$\tau_a = 0$

Bending shear $\Rightarrow \tau_{b,a} = \frac{kVQ}{It} =$



END OF EXAM - GOOD LUCK

at surface during rotation $\tau_m = 0$

Page 2 of 2

at A_2:

Eq. 55.56 $\Rightarrow \sigma_a', \sigma_m'$

$\Rightarrow \left(\frac{n_2 \sigma_a'}{S_e}\right)^2 + \left(\frac{n_2 \sigma_m'}{S_{ut}}\right)^2 = 1$

$n_2 =$

Eq. 55.56 at A_1 $\Rightarrow$

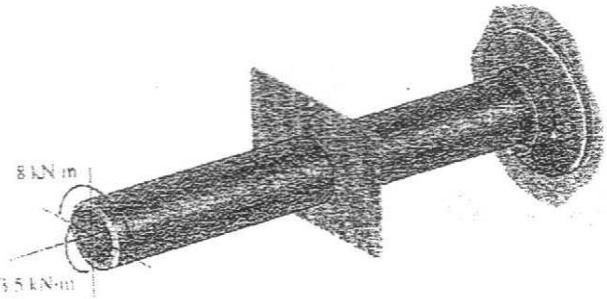
$\sigma_a' =$

$\sigma_m' =$

$\Rightarrow \left(\frac{n_1 \sigma_a'}{S_e}\right)^2 + \left(\frac{n_1 \sigma_m'}{S_{ut}}\right)^2 = 1$

$n_1 =$

4) (10 Points) The steel pipe shown in the figure has an inner diameter of 60 mm and an outer diameter of 80 mm. If it is subjected to a torsional moment of 8 kNm and a bending moment of 3.5 kNm, determine the principal stresses and the maximum shear stress.



$M = 3.5\ KN.m$

$T = 8\ KN.m$

⇒ The first step is to calculate the resulted stresses.

$$\sigma_x = \frac{Mc}{I} = \frac{(3500)(0.04)}{\frac{\pi}{4}\left((0.04)^4 - (0.03)^4\right)} = 101.9\ MPa$$

$$\tau = \frac{Tc}{J} = \frac{(8000)(0.04)}{\frac{\pi}{2}\left((0.04)^4 - (0.03)^4\right)} = 116.4\ MPa$$

the principal stresses are given by the following when $\sigma_y = 0$:

$$\sigma_1, \sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$\sigma_1, \sigma_2 = \frac{101.9 + 0}{2} \pm \sqrt{\left(\frac{101.9 - 0}{2}\right)^2 + (116.4)^2} =$$

⇒ the max. shear is given by:

$$\tau_{max} \Rightarrow \tau_1, \tau_2 = \pm\sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = \pm\sqrt{\left(\frac{101.9 - 0}{2}\right)^2 + (116.4)^2}$$

(End of Exam)

Instructor: Dr. Momen Sughayyer
Date: October 28, 2009
Time: 75 Minutes (Part I + Part II)

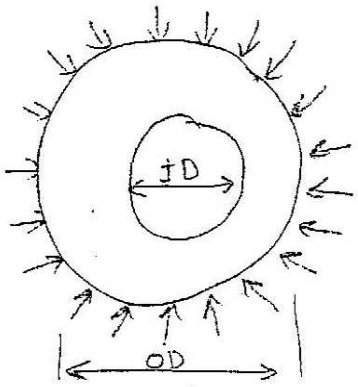
Student Name:.....
Student Number:.....
Section:.....

Part II – Open Book Only

Q3) (10 Points) A cold-drawn AISI 1015 steel tube has an ID of 200 mm and OD of 300 mm is to be subjected to an external pressure caused by a shrink fit. What maximum pressure would cause the material of the tube to yield?

AISI 1015 CD steel

ID = 200 mm
OD = 300 mm



from tables (A-20) $\Rightarrow S_y = 320$ MPa

Suppose $P_i = 0$

$\Rightarrow$ Since there is no shear stress on surface is this case, the three stresses σ_t, σ_r, and σ_l are the principal stresses.

$\Rightarrow$ Also, since there is no longitudinal constrains $\sigma_l = 0$.

$\Rightarrow$

$$\sigma_t = \frac{-r_o^2 P_o}{r_o^2 - r_i^2}\left(\frac{r_i^2}{r^2} + 1\right)$$

$$\sigma_r = \frac{r_o^2 P_o}{r_o^2 - r_i^2}\left(\frac{r_i^2}{r^2} - 1\right)$$

} given the fact that the sign is for the stress direction, σ_t is the largest normal principal stress, and max. will be at $r = r_i$

$$\sigma_t = 320 \times 10^6 = -\left(\frac{0.15^2 P_o}{0.15^2 - 0.1^2}\right)\left(\frac{0.1^2}{0.15^2} + 1\right)$$

$$P_o =$$

ε

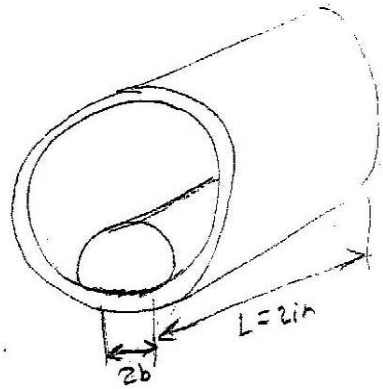
3) (*10 Points*) An aluminum alloy roller, with diameter 1 in and length 2 in, rolls on the inside of cast-iron ring having an inside radius of 4 in, which is 2 in thick. Find the maximum contact force *F* that can be used if the octahedral shear stress is not to exceed 4kpsi.

From Table A-5 / pp 1007

For aluminum: $E_a = 10.4$ Mpsi, $\nu_a = 0.333$, $d_a = 1$ in

For cast iron: $E_c = 14.5$ Mpsi, $\nu_c = 0.211$, $d_c = -8$ in

$L = 2$ in



Using eq. 3.73 / pp 124

$$b = \sqrt{\frac{2F}{\pi L}\,\frac{(1-\nu_a^2)/E_a + (1-\nu_c^2)/E_c}{1/d_a + 1/d_c}}$$

$$b = \alpha\sqrt{F}$$

Given that τ_{max} occurs at $\frac{z}{b} = 0.78 \Rightarrow \tau_{max} = 0.3 P_{max}$

$$\tau_{max} = 4 \times 10^3 = 0.3\, P_{max}$$

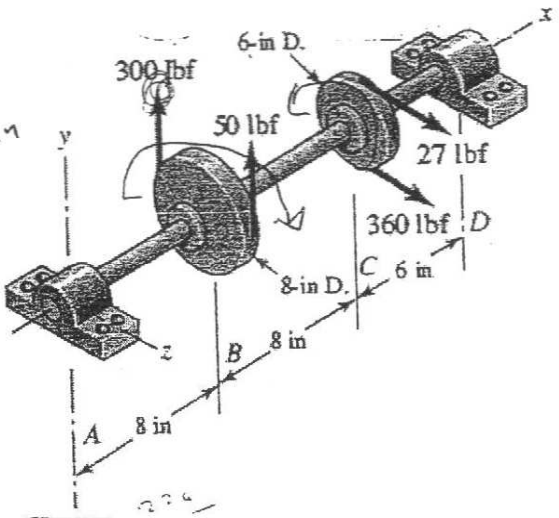
Using eq. 3.74 / pp 124:

$$P_{max} = \frac{2F}{\pi b L}$$

$$4 \times 10^3 = 0.3 * \frac{2F}{\pi(\alpha\sqrt{F})L} \Rightarrow F =$$

END OF EXAM – GOOD LUCK

Q4) (10 Points) The figure shows a shaft mounted in bearings at A and D and having pulleys at B and C. The forces shown acting on the pulley surfaces represent the belt tensions. The shaft is to be made of ASTM grade 25 cast iron using a design factor $n_d = 2.8$. What diameter should be used for the shaft?



$T_C = (360 - 27)(3) = 1000$ lbf in

$T_B = (300 - 50)(4) = 1000$ lbf in

In xy

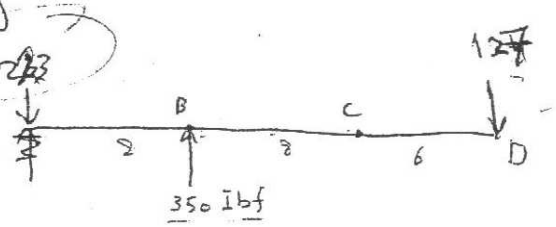
$M_B = 223(8) = 1784$

$M_C = 127(6) = 762$

In xz

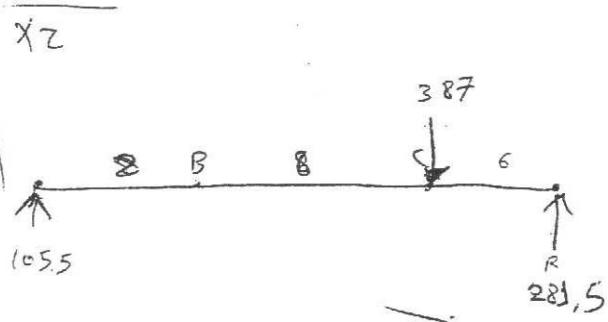
$M_B = 105.5(8) = 848$

$M_C = 281.5(6) = 1685$



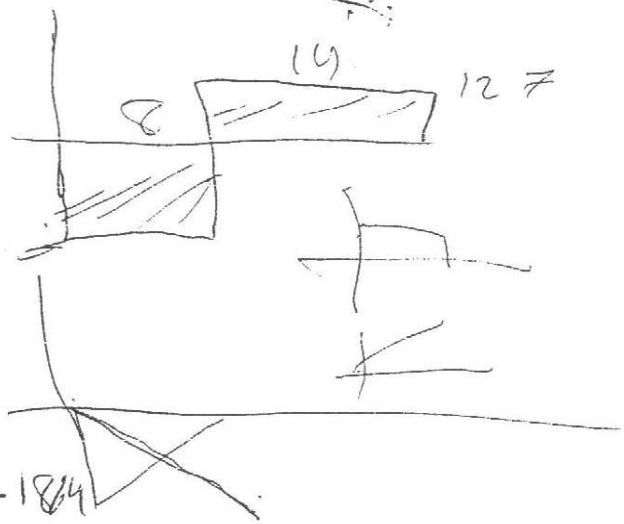
$M_B = \sqrt{1784^2 + 848^2} = 1975.3$

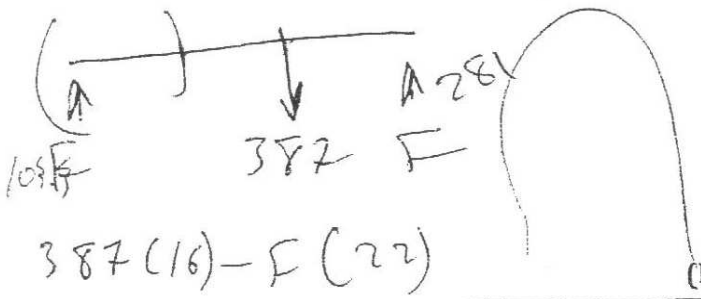
$M_C = \sqrt{762^2 + 1685^2} = 1850.4$



$\tau = \frac{16T}{\pi d^3} = \frac{16(1000)}{\pi (6)^3} = 23.6$

$\sigma = \frac{32M}{\pi d^3} = \frac{32(1850)}{3.14(}$





$387(16) - F(22)$

(End of Exam)